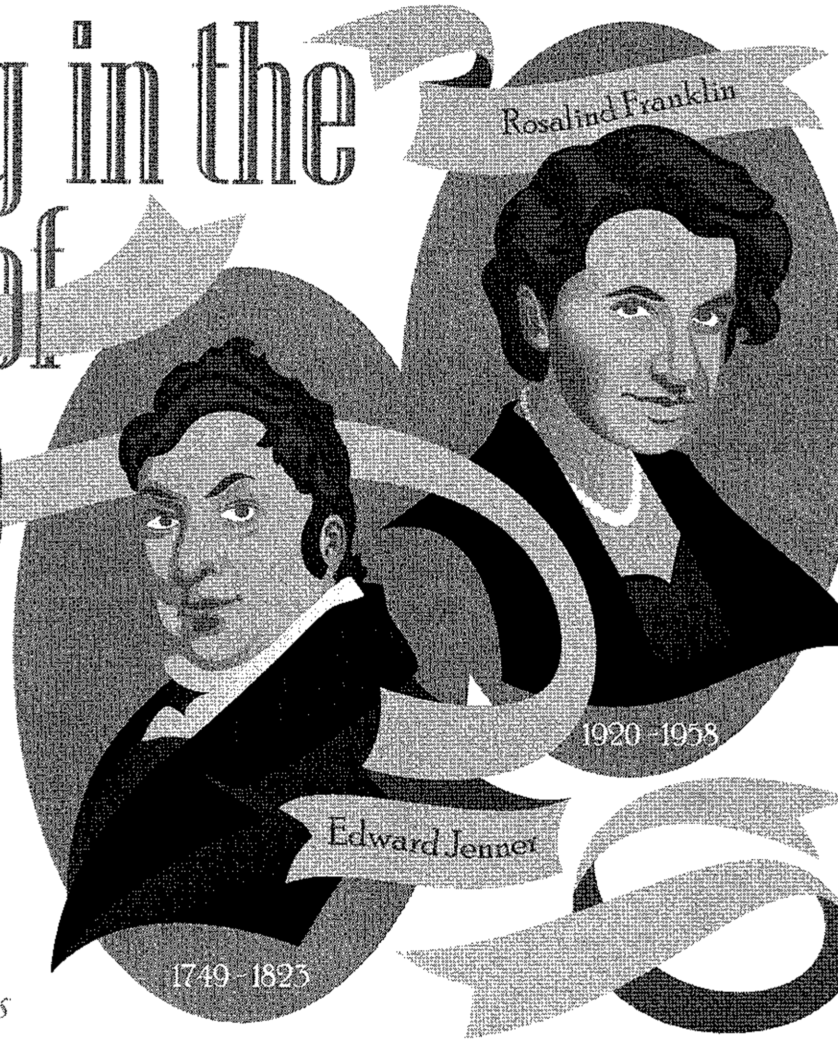
Weaving in the Story of Science

Incorporating the nature of science into the classroom through stories about scientists, discoveries, and events



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Incorporating stories in the science classroom transforms students from a group of passive learners into a community of active scientists. I use the term *stories* loosely to describe the literature I use in my classroom, such as news articles and adapted biographies of scientists from books and websites. I also use sections from government reports or magazine articles in my lesson plans and, at times, write my own narratives to serve the particular purposes of my lesson.

I use stories to incorporate the nature of science into my 10th-grade biology classes and to teach topics that do not lend themselves to inquiry labs or in-depth case studies. Stories serve as a vehicle for creating continuity in my curriculum. Whether we read short historical narratives about scientists or current event articles, stories weave common elements of the nature of science between topics and activities. Stories also can help students realize the important contributions of women, persons of color, and other traditionally underrepresented groups. Stories are a nice fit for lessons when inquiry-based labs do not work for the topic or time limits restrict lab activities.

According to the *National Science Education Standards*, inquiry helps students understand both content and the nature of science and provides students with an "appreciation of how we know what we know" (NRC 1996, p. 105). Inquiry involves critical thinking, reasoning, hypothesizing, and testing, but the Standards also emphasize the importance of "history in school science programs to clarify different aspects of scientific inquiry [and] the human aspects of science" (NRC 1996, p. 107). Inquiry-based labs are not the only way to teach students these skills. In this article, I discuss how to use stories to engage students in both scientific inquiry and the nature of science.

Edward Jenner biographical excerpt.

In 1796, [Jenner] carried out his now famous experiment on eight-year-old James Phipps. Jenner used pus taken from a cowpox pustule and inserted it into an incision on the boy's arm. He was testing his theory, drawn from the folklore of the countryside, that milkmaids who suffered the mild disease of cowpox never contracted smallpox, one of the greatest killers of the period, particularly amongst children. Jenner subsequently demonstrated that having been inoculated with cowpox, Phipps was immune to smallpox. He submitted a paper to the Royal Society in 1797 describing his experiment but was told that his ideas were too revolutionary and that he needed more evidence. Undaunted, Jenner experimented on several other children, including his own eleven-month-old son. In 1798, the results were finally published, and Jenner coined the word *vaccine* from the Latin *vacca* for cow. Jenner was widely ridiculed. Critics, especially the clergy, claimed it was repulsive and ungodly to inoculate someone with material from a diseased animal (BBC).

Using stories in the classroom

To incorporate reading into my curriculum, I select a story and ask students to read it as homework. Sometimes I read the story aloud in class, dramatizing it with my voice and actions. Reading aloud is helpful for students with reading disabilities and can therefore facilitate the activity. Prior to the reading activity, I have students write in a journal or discuss their ideas about the story's topic to determine prior knowledge, as well as to engage them metacognitively. For example, if we are going to read a story that involves the process of science, I ask students what they know about scientific inquiry, such as, "Do all scientists use the same method?" and "What steps are involved?" As a class, we often revisit these questions throughout the year, which allows students a chance to reflect on how their thinking has changed.

After the reading, students engage in large- or small-group discussions, think-pair-share, or journal exercises about other questions I have prepared in advance. The entire activity is short (less than 15–20 minutes), so the stories I use are generally less than two typed pages and require about 5 minutes to read. Occasionally the stories are longer, but often the readings are part of other activities that address content more explicitly.

The following four examples of reading activities address the nature of science and scientific inquiry, but can also be modified to teach content knowledge or used as assessment tools. The activities illustrate various ways in which stories are used in my biology classes. The same principles and questions I address with these examples can easily be transferred to other science content areas with minor modifications.

Edward Jenner and the discovery of vaccines

After my class has covered the microscopic world of viruses, I give students a short biography on Edward Jenner to engage them in the nature of science and help them learn about vaccination. The biography is found on the British Broadcasting Company's (BBC) Historic Figures website (see "Edward Jenner biographical excerpt" for a section of this biography).

In the discussion following the story, I ask students a number of questions starting with, "What surprised you from this biography?" Students usually cannot believe that Jenner tested his hypothesis on his own son. I then direct the conversation into areas related to the nature of science:

- Why was Jenner interested in preventing smallpox?
- How does Jenner exhibit scientific thinking and inquiry?
- What was Jenner's hypothesis? What observations did Jenner base his hypothesis on? How did he test it?
- Was Jenner's test ethical?
- How did the scientific community and society respond to Jenner's finding and why?

Discussion is lively and each time I use this biography in class, I sense that students are immersed in the history and nature of science. Not only do students learn how vaccines "trick" the body, they also learn that science does not occur in a vacuum, but instead is influenced by the larger community. A full inquiry lab is not feasible for my lesson on viruses, but using this biography is a great way to involve students in authentic science.

Mystery reptiles?

Stories about mystery creatures are as old as time. While searching the internet for material about birds and reptiles, I came across an article in the *Cortez Journal* (Heidelberg 2002) about sightings of a mysterious "river dinosaur" in the American southwest. The focus of a recent *Mystery Hunters* episode on Discovery Kids Channel (2006), the existence of a river dinosaur has never been confirmed because one has not been found dead or alive; the only evidence of the mystery creature is contained in eyewitness reports. The newspaper article includes comments from eyewitnesses who describe where they supposedly saw the creature, what it looked like, and some of its behaviors (eyewitnesses describe the creature as a cross between a bird and a dinosaur).

I use this article in my classroom to explore the ideas of evidence and the differences between scientific and nonscientific evidence. I begin by asking students to comment on the article: "Do you believe it? Why or why not?" and "Do you think the river dinosaur is real?" I then ask students to support their arguments with evidence from the article and ask what additional evidence they would

require to be more certain about the reality of the river dinosaur We also discuss what type of evidence scientists would require and how it would be different from the eyewitness testimony Nikolai Sucik, the investigator quoted in the article, has a colorful history as a cryptozoologist (i.e , mysterious creature investigator), which leads to classroom discussion about the different realms of science and pseudoscience We also discuss how the article would be received if it appeared in *National Geographic* magazine or *The National Enquirer*.

Each time I conduct this exercise, I am surprised that this short article convinces many students that the "river dinosaur" exists. Students' misconceptions regarding evidence and scientific thinking become apparent during this exercise, and I am able to address these misconceptions further in other areas of the curriculum. Interestingly, much of the mystery concerning the river dinosaur has yet to be resolved. A few other news outlets picked up the story, but nothing conclusive has been reported about the existence of a living river dinosaur and what kind of creature it is, although speculation abounds.

FIGURE 1

Nature of science rubric.

	Naïve	Developed
Understandings about scientific inquiry		
Scientific methods	Student indicates that there is only one scientific method that follows the same procedures at all times, including creating a hypothesis controlled experimentation, data collection, and conclusions. Student states that theories do not play a role in guiding research.	Student recognizes that there are many scientific methods, which are determined by the topic of study and the interests of the researcher The methods may involve controlled experimentation, observational studies, and field studies Theories underlie and influence research.
Evidence	Student does not recognize the role of evidence in scientists' conclusions.	Student recognizes and cites evidence in discussing scientists' conclusions.
Science as a human endeavor		
Collaboration	Student cites that scientists typically work alone and serendipitously make discoveries	Student recognizes that scientists generally work in collaboration with many others and scientific advancement depends on the efforts of many scientists.
Influences on scientific research	Student sees science as an entity outside the influence of culture, society, and personal characteristics Student indicates that scientists serve only to illuminate science to the public and are completely objective	Student recognizes and discusses the influences and motivations of scientists, how these affect what they study, and their interpretations and conclusions Student discusses how society interacts with and guides scientific research.
Nature of scientific knowledge		
The changing nature of scientific knowledge	Student states that scientific knowledge is ultimate truth and unchangeable, or changes are instantaneous, and not based on empirical methods.	Student states that scientific knowledge can change and is often incomplete and tentative
Characteristics	Student fails to distinguish scientific knowledge from pseudoscience	Student recognizes that scientific knowledge is supported by logical investigation and empirical methods and is different from pseudoscience

Rosalind Franklin and the structure of DNA

The discovery of the structure of DNA is a great example of scientific process in action, and highlighting Rosalind Franklin's role engages students in the complex social aspects involved in scientific work Although it is geared toward middle school students, I use the book *Uncovering the Structure of DNA* (Phelan 2003) to introduce students to Franklin, as the resource is already built into my curriculum for a timeline project and also works well for students with reading disabilities. To further illuminate Franklin's role without reducing her to a simplistic caricature, students also read modified portions of a *Physics Today* article (Elkin 2003), in particular the sections that discuss Franklin's conflicts with colleagues, and her personality and contributions. As students work through the readings, we discuss the following:

- Which scientist made the "most important" contribution to this discovery? (This seems to ignite much debate as students realize that it is impossible to pin down the *most important* scientist.)

Helpful resources.

Finding appropriate stories to use in the classroom can be a difficult task. The following list of internet resources and books may be helpful:

Bryson, B. 2003. *A short history of nearly everything.* New York: Broadway Books. Includes longer stories (around 20 pages) about many topics of scientific interest. I often take sections (a few pages) of the chapters to use with my students. The reading level would be most appropriate for the upper grades (10–12).

Hakim, J. *The story of science* (series). Provides compelling, accessible stories from the history of science from Aristotle to Einstein.

Horvitz, L. 2002. *Eureka! Scientific breakthroughs that changed the world.* New York: John Wiley and Sons. Includes longer stories (15–20 pages) about Alexander Fleming, Charles Darwin, James Watson, and Francis Crick, among others. The stories are fast-paced and provide a survey of important discoveries.

New York Times Science news. *www.nytimes.com/pages/science/index.html*. Contains a variety of articles about all areas of science and highlights recent discoveries.

University of California Museum of Paleontology. History of evolutionary thought. *http://evolution.berkeley.edu/evolibrary/article/0_0_0/history_01*. Includes stories about discoveries related to evolutionary theory in various scientific fields. Highlights the contributions of individual scientists and also traces concept development over time.

Weisstein, E. World of scientific biography. *http://scienceworld.wolfram.com/biography*. Possible to search for scientists by branch of science, minority, gender, or nationality. Includes very short biographies, but also links to more extensive biographies.

WGBH. A science odyssey: People and discoveries. *www.pbs.org/wgbh/aso/databank*. Contains various scientist biographies, but also stories about important discoveries of the 21st century.

- How did each scientist study DNA? What different methods and techniques were used? In what ways were the scientists' backgrounds different?
- In what ways were the collaborations among the different scientists important? How did they treat each other? What does this tell you about what society and the scientific community were like at that time? What were some of the difficulties between Franklin and the other scientists? Why was Franklin not awarded the Nobel Prize? Do you think similar incidents would happen today? Why or why not?
- What have we learned about DNA since the 1950s? How has our knowledge of DNA changed?

Even though it may be difficult for some students to thoughtfully engage in these issues as traditional notions of science and equality are challenged, studying Franklin is important because it prompts discussion about the difficulties women often experienced (and may continue to experience) in scientific research. Studying Franklin allows students to delve into the difficulties inherent in science that extend beyond experimentation and expose them to authentic science, which is often personality-driven.

Science and culture

Incorporating cultural aspects of science into the classroom is difficult, as textbooks often present minority scientists as simply an "extra" in the curriculum (AAAS Project 2061 Textbook Evaluations). However, the Society for the Advancement of Chicanos and Native Americans in Science's (SACNAS) excellent website, The Biography Project *(www.sacnas.org/biography)*, contains short biographies of over 70 contemporary Chicano and Native American scientists in biology, chemistry, physics, and Earth science. These biographies reveal to students the integral role of culture in the nature of science.

Most of the biographies on the SACNAS site include versions adapted for both middle and high school reading levels and are written in the first person. The majority of the biographies include background information about what influenced the person to become a scientist and what he/she currently researches. The biographies often provide a nice segue or introduction to a topic and allow students to engage in the cultural and personal influences on scientific work. A typical series of questions my students work through includes:

- How did the scientists' upbringing influence his/her decision to become a scientist?
- What role does his/her culture play in what he/she researches?
- How might a scientist of a different culture study this topic? How could someone else focus on a different aspect of this topic? How would you study this topic?
- What motivates this scientist? Why does he/she study this topic?

While not all of the biographies specifically address culture, they all include the personal dimension inherent in scientific work and allow students to see scientists as real people with dreams and motivations.

Assessing understanding

I would like to be more explicit in my assessment of students' understandings of the nature of science before and after introducing various stories, but even the research

community disagrees about what the nature of science actually is (Alters 1997) and how to best determine if students understand the elements of it (Driver et al. 1996). Reviewing journal entries is helpful and provides insight into this complex topic, and I use a rubric that can be adapted according to the lesson's goals (Figure 1, p. 35). Most of all, I am excited to anecdotally witness greater curiosity in my students and see them open their minds to diverse ways of thinking about science.

Although the greatest gains I have noticed in my students are increased enthusiasm and curiosity, gains in their understanding of the nature of science and inquiry are more difficult to determine. Students seem to raise more questions during our discussions, and their journal entries reveal greater excitement and open-mindedness about scientific inquiry. For example, comments such as "I never thought about it before" and "I guess I do not really think like a scientist" reveal that my students are grappling with ideas and ways of thinking that are new to them and sometimes difficult to integrate with their current understandings of science.

By using stories, my biology curriculum has become more coherent. An atmosphere of scientific inquiry permeates my classroom labs, readings, discussions, and lectures. Stories return the human element to science and invite students to place themselves in the shoes of great scientists and think scientifically about current events. ■

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References

Alters, B. 1997. Whose nature of science. *Journal of Research in Science Teaching* 34(11): 39–55.

British Broadcasting Company (BBC). Historic figures: Edward Jenner (1749–1823). *www.bbc.co.uk/history/historic_figures/jenner_edward.shtml*

Driver, R., J. Leach, R. Millar, and P. Scott. 1996. *Young people's images of science*. Bristol, PA: Open University Press.

Elkin, L.O. 2003. Rosalind Franklin and the double helix. *Physics Today* 56(3): 42–49.

Heidelberg, K. *Cortez Journal*. 2002. Mystery Reptile Loose in County? June 30.

Mystery Hunters II. 2006. River Dino, Ghost Town. Montreal, Canada: Apartment 11 Productions.

National Research Council (NRC). 1996. *National science education standards*. Washington, DC: National Academy Press.

Phelan, G. 2003. *Uncovering the structure of DNA (Reading expeditions: Scientists in their times)*. Washington, DC: National Geographic Society.

Project 2061 Textbook Evaluations. *High school biology textbooks: A Benchmarks-based evaluation*. American Association for the Advancement of Science. *www.project2061.org/publications/textbook/hsbio/report*

Asking the right questions.

The following framework of concepts and questions can be discussed with students to address the nature of science through stories. The sections are arranged according to different student understandings emphasized in the *National Science Education Standards* (NRC 1996); depending on the content of the story, lesson goals, and students, the questions and topics can be adjusted.

Understandings about scientific inquiry (p. 173)

- Ask students to discuss the scientific methods involved in the story. Trace the process the scientist(s) went through. Discuss the predictions, hypothesis, data collection, testing, communication of results, and evidence. Discuss how the experiment could have been conducted or data collected differently. Talk about skills the scientist(s) needed for the investigation. Discuss how the "method" differs from other stories discussed in class. Discuss the theory that guided the research.
- Discuss the nature of the evidence collected. Is the evidence adequate? What would strengthen or weaken the conclusions drawn from the data? Is the source/scientist reliable?

Science as a human endeavor (p. 200)

- Ask students to discuss who are acting as scientists in this story. Which people are exhibiting scientific attitudes? Challenge students to think of ways when they have acted scientifically.
- Discuss what motivated the scientist(s). What forces (societal, scientific, personal, cultural) drove the investigation?
- Discuss how society influenced the scientist and vice versa.
- Talk about the ethical issues related to the story. What forces drive ethical scientific practices?
- Discuss the various people involved in the scientific work. Who laid the foundation of the work being done? How did others contribute to the discovery in scientific and nonscientific ways?

The nature of scientific knowledge (p. 201)

- Discuss how the evidence presented clashes with or supports current scientific ideas.
- If using a story about a historical discovery, discuss how our knowledge has changed since the time of the discovery (e.g., evolution or cell theory).
- Discuss how the knowledge described in the story is incomplete. Have students brainstorm what additional questions they have about the knowledge presented.